Forces and Motion

PS-5 The student will demonstrate an understanding of the nature of forces and motion.

PS-5.7 Explain the motion of objects on the basis of Newton's three laws of motion: inertia; the relationship among force, mass, and acceleration; and action and reaction forces.
Taxonomy Level: 2.7-B Understand Conceptual Knowledge

Key Concepts:
Newton's 1st Law: Law of Inertia, net force, newton (N), inertia, friction
Newton's 2nd Law: applied force
Newton's 3rd Law: Law of Action and Reaction, action force, reaction force

Previous/Future knowledge: In 5th grade students are introduced to net force as they explain how unbalanced forces affect the rate and direction of the motion in object (5-5.3). Also in 5th grade students explain how a change in force or mass affects the motion of an object (5-5.6). In 8th grade, as foundation for Newton's first law, students summarize and illustrate the concept of inertia (8-5.6). Also in 8th grade, as foundation for Newton's second law, students predict how varying the amount of force or mass will affect the motion of an object (8-5.4). In Physical Science, students have an understanding of the difference between constant velocity and accelerated motion. Students can now use Newton's first law of motion to explain how an object's inertia affects its motion in terms of speed and direction. Students can use Newton's second law to explain how applied forces can affect the motion of an object in terms of speed and direction. Newton's third law is an entirely new concept for Physical Science students.

Newton's First Law of Motion
It is essential for students to understand

- That a force is a push or a pull that one object exerts on another object and that in the metric system, force is measured in units called *newtons* (N).
- That a *net force* is an unbalanced force. It is necessary to find the net force when one object has more than one force exerted on it.
- *Newton's First Law* that states that the velocity of an object will remain constant unless a net force acts on it. This law is often called the *Law of Inertia*.
  - If an object is moving, it will continue moving with a constant velocity (in a straight line and with a constant speed) unless a net force acts on it.
  - If an object is at rest, it will stay at rest unless a net force acts on it.
  - *Inertia* is the tendency of the motion of an object to remain constant in terms of both speed and direction.
- That the amount of inertia that an object has is dependent on the object's mass. The more mass an object has the more inertia it has.
- That if an object has a large amount of inertia (due to a large mass):
  - It will be hard to slow it down or speed it up if it is moving.
  - It will be hard to make it start moving if it is at rest.
  - It will be hard to make it change direction.
- That inertia does not depend on gravitational force. Objects would still have inertia even if there were no gravitational force acting on them.
- The behavior of stationary objects in terms of the effect of inertia. Examples might include:
  - A ball which is sitting still will not start moving unless a force acts on it.
  - A ball with a larger mass will be more difficult to move from rest than a smaller one. It is more difficult to roll a bowling ball than a golf ball.

- The behavior of moving objects in terms of the effect of inertia. Examples might include:
  - People involved in a car stopping suddenly:
    - If a net force (braking force) is exerted on the car in a direction opposite to the motion, the car will slow down or stop.
    - If the people in the car are not wearing their set belts, because of their inertia, they keep going forward until something exerts an opposite force on them.
    - The people will continue to move until the windshield (or other object) exerts a force on them.
    - If the people have their seatbelts on when the braking occurs, the seatbelt can exert a force to stop the forward motion of the person.
  - A passenger in a turning car:
    - Consider a person who is a passenger in a car that is moving in a straight path. The passenger in the car is also moving in a straight path.
    - If the car suddenly turns left, the inertia of the passenger causes him to continue to move in the same straight path even though the car under him has turned to the left.
    - The passenger feels as if he has been thrown against the side of the car, but in fact, the car has been pushed against the passenger.
  - If a rowboat and a cruise ship are moving at the same speed, it is more difficult to turn the cruise ship because it has more mass and therefore more inertia.
- The reason that objects often do not keep moving in our everyday experience is because there is often a net force acting on them.
  - Students need to explain how *friction* as a net force slows or stops a variety of everyday objects.
  - If a ball were thrown in distant outer space away from forces, such as friction, it would continue to move at a constant velocity until an outside force acts on it.

Newton's Second Law of Motion
It is essential for students to understand

- *Newton's Second Law* that states, "When a net force acts on an object the object will accelerate in the direction of the net force".
  - The larger the net force, the greater the acceleration. (It is sometimes stated that the acceleration is directly proportional to the net force.)
  - The larger the mass of the object, the smaller the acceleration. (It is sometimes stated that the acceleration is inversely proportional to the mass of the object.)
- In mathematical terms Newton's Second Law states that the net force equals the mass times the resulting acceleration. ($F = ma$)
- Acceleration can mean speeding up, slowing down, or changing direction;
- Friction and air resistance will often be ignored in discussions and problems, but students should be aware of their role in determining the net force.

It is essential that students understand

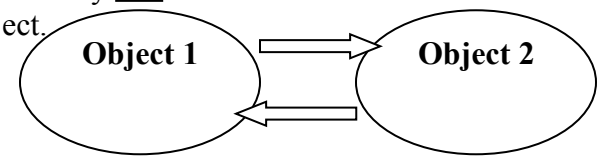
- The motion of objects in terms of force, mass and acceleration.
- *The effects of force***:**
  - *Force magnitude*: If the mass of an object remains constant, the greater the net force the greater the rate of acceleration.

- *Force direction:*
  - If the force is applied to an object at rest, the object will accelerate in the direction of the force.
  - If the force is applied to a moving object in the same direction that the object is moving, the object will accelerate so its speed will increase to a greater speed and continue to travel in the same direction.
  - If the force is applied to a moving object in a direction opposite to the direction that the object is moving, the object will have negative acceleration and slow down from its speed before the force was applied to a slower speed. It will either continue at the slower speed, stop, or begin to move in the opposite direction, depending on the magnitude of the force.

- *The effect of mass:*
  - If the same net force is applied to two different objects, the object with the smaller mass will have a greater acceleration in the direction of the applied force.

It is not essential for students to
- Address forces in directions other than the same or opposite;
- Understand the factors that affect friction;
- Differentiate sliding and rolling friction.

Newton's Third Law of Motion
It is essential for students to understand
- *Newton's Third Law* that states, "When one object exerts a force on a second object, the second one exerts a force on the first that is equal in magnitude and opposite in direction."
  - This law is sometimes called the "*Law of Action and Reaction*".
  - Even though the forces are equal in magnitude and opposite in direction, they do not cancel each other. This law addresses **<u>two</u>** objects, each with only **<u>one</u>** force exerted on it.
    - Each object is exerting one force on the other object.
    - Each object is experiencing only one force.



- Students should describe the motion of familiar objects in terms of action and reaction forces. Examples may include:
  - A swimmer is accelerating forward:
    - The swimmer pushes against the water (action force), the water pushes back on the swimmer (reaction force) and pushes her forward.
  - A ball is thrown against a wall:
    - The ball puts a force on the wall (action force), and the wall puts a force on the ball (reaction force) so the ball bounces off.
  - A person is diving off a raft:
    - The person puts a force on the raft (action force) pushing it, and the raft puts a force on the diver (reaction force) pushing her in the opposite direction.
  - A person pushes against a wall (action force), and the wall exerts an equal and opposite force against the person (reaction force).

It is not essential for students to understand or solve problems involving momentum.

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Assessment Guidelines:

The objective of this indicator is to *explain* the motion of objects based on Newton's laws of motion, therefore, the primary focus of assessment should be to construct a cause and effect model that explains the motion of objects in terms of inertia; force, mass, and acceleration; and action and reaction forces.

In addition to *explain*, assessments may require that students:

- *Exemplify* Newton's Laws of Motion;
- *Compare* the inertia of different objects of different mass;
- *Compare* the rate of acceleration of objects with different masses or the rate of acceleration of an object when subjected to different forces (in terms of magnitude and direction);
- *Compare* action and reaction forces in terms of magnitude, direction, source of force (which object) and recipient of the force (which object);
- *Summarize* the principles of Newton's Laws of Motion;
- *Illustrate* Newton's Laws of Motion with pictures, words, or diagrams.